OST TECHNICAL PROGRESS REPORT
TEAM WORK PLAN–FY 1999 RESULTS

Clean Water Team

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DESCRIPTION:

During FY99, the research activities of the Clean Water Team (CWT) supported the environmental research needs of the region, and received financial support from either EPA Region III or PA DEP. Water treatment research investigated both passive and active treatment technologies for the remediation of coal mine-pool drainage. Passive treatment activities **(Project A)** included the continuation of long-term monitoring of existing unit treatment operations and the development of selection and sizing criteria for newly developed systems. In addition, a new "semi-passive" treatment design for large-flow discharges **(Project B)** was begun, in cooperation with a local watershed association, which has received state funding for the construction. This treatment process will address novel sludge removal and pre-aeration aspects. Another "semi-passive" treatment activity involved the construction of a pilot-scale water-powered treatment system **(Project C)**. This approach is envisioned to be used in conjunction with passive treatment systems or as a stand-alone active treatment operation. A pilot-scale demonstration of an active treatment, using bacterial sulfate reduction treatment (BSRT)**(Project D)**, was actively pursued at the Berkley Pit in Montana. The BSRT process, developed by NETL, results in the selective recovery of metals from severely contaminated mine water. Recovered metals can then be sold to a smelter to off-set water treatment costs. Research activities also focused on engineering the physical properties of mine water treatment waste material, or sludge **(Project E)**. These activities included an evaluation of combining acid mine drainage (AMD) sludge with coal combustion byproducts (CCB) as a means of dewatering and solidifying the waste materials.

Geophysical investigations **(Project F)** focused on: (1) identifying water pollution sources on a regional or watershed basis and (2) development of prevention/control techniques. The capabilities of airborne or remote sensing technologies were evaluated to determine if water pollution sources could be identified on a river- and watershed-basis. Ground-truthing and evaluation of remote sensing data were also performed. In previous years, ground-based geophysical techniques (terrain conductivity and very low frequency) were used successfully by NETL to locate water loss zones in small streams. Although water loss zones in a waterway can be a natural occurrence (groundwater recharge), these zones can also be sources of recharge to polluted mine pools and a major contributor to the surface water pollution at some point down-gradient, particularly in the Appalachian region. It is also difficult to determine the impact of water pollution on a river that is caused by the artesian flow of mine pool water through fractures in the overburden. Consequently, research efforts included a water quality synoptic survey of the Lower Youghiogheny River Basin and additional investigations with land-based geophysical techniques. The objective here was to determine if artesian discharges of groundwater (through non-point sources along the river banks and within its channel) or surface water flow (from tributaries) was the major source of pollution in this river.

RESEARCH OBJECTIVES:

- To develop selection and sizing criteria for newly developed passive treatment systems, and to investigate and solve potential and existing problems associated with these systems (Project A).
- To develop low cost options for remediation of large abandoned underground mine pool discharges that can be inexpensively maintained by a grass roots watershed organization (Projects B&C).
- To implement the transfer of BSRT to industry (Project D).
- To provide more attractive options with respect to metals removal (sludge) for individuals developing strategies for watershed remediation and actively treating contaminated water (Project E).
- To develop practical field techniques for conducting geophysical surveys on a river or waterway that cannot be waded (Project F).
- To conduct ground-based geophysical surveys at selected sites on the Youghiogheny River to determine if the ability exists to locate zones of water loss or gain within the river channel (Project F).
- To identify and implement available remote sensing technologies and platforms that can be effective and economical in identifying water pollution sources on a watershed or regional basis (Project F).
- To conduct a synoptic water quality survey of the Lower Youghiogheny River Basin and to use the data to evaluate various remediation options with respect to potential benefits and associated costs (Project F).

LONG TERM GOALS/RELATIONSHIP TO NETL's PRODUCT LINE:

The FY 99 research of the Clean Water Team was based on priorities established by the Watershed Management Product Line and EPA Region III. Long term goals included:

- Evaluate the long-term performance of established passive treatment unit operations (Project A).
- Develop and document more efficient passive treatment technologies that can be used to inexpensively improve watershed water quality (Projects A and B).
- Develop inexpensive, easily maintained, water-powered treatment devices that can be used to clean up existing pollution problems on a watershed basis throughout the nation (Project C).
- Educate industry, academia, and the environmental regulatory agencies on the proper use of BSRT, and encourage its use for appropriate applications (Project D).
- Enhance the overall process economics for remediation of watersheds (Projects E and F).
- Develop a regional plan for addressing the water pollution problems on a river and/or watershed basis (Project F).
- Develop techniques for conducting land-based geophysical surveys on rivers (Project F).
- Establish procedures for access to applications of existing DOD and/or DOE remote sensing technology (Project F).

SUMMARY OF ACCOMPLISHMENTS:

Water quality data was analyzed to document and evaluate the performance of various types of passive systems for the treatment of mine drainage. This monitoring program enabled the evaluation of nine anoxic

limestone drains (ALDs), eight reducing and alkalinity producing systems (RAPS, aka SAPS), 21 ponds and wetlands, and 10 complete passive treatment systems containing various unit operations (ALDs, RAPS, ponds, and wetlands). We also evaluated the Maelstrom oxidizer, a low-cost aeration system that is being used in conjunction with aerobic wetlands to reduce the areal requirements of such wetlands. This "semi-passive" approach could significantly increase the efficiency of aerobic wetlands, thereby increase their applicability to a much broader range of water quality ans quantity.

A proposal was prepared and submitted to the PA DEP for funding the construction and monitoring of a passive system to treat the Brinkerton discharge. The Brinkerton discharge drains a subterranean mine pool in Westmoreland County, PA. The effluent from these abandoned coal mines is the principal non-point source of pollution in the Sewickley Creek watershed and has a major impact on the water quality in the lower Youghiogheny River. The proposal has been selected for funding. Preliminary experiments indicated that significant increases in pH could be achieved by agitation of the discharge water. This increase in pH is due to out-gassing of dissolved carbon dioxide, and is important for the rapid oxidation and removal of the iron contamination. This site-specific information will be used to tailor the remediation project.

Pilot-scale testing was successfully completed using NETL's patented In-Line System at an abandoned mine adjacent to the Loriberry Creek, which is the major pollution source (tributary) in the Swatara Creek Watershed. A limestone diversion well was successfully installed near the headwaters of Loriberry Creek. Also, a pilot-scale water-powered treatment facility was installed below the limestone diversion well. This facility lends itself to a variety of conventional and non-conventional treatment testing approaches.

Berkeley Pit water was successfully treated using bacterial sulfate reduction. The treated water met applicable discharge standards, and salable copper and zinc concentrates were recovered. An analysis of the projected recovered costs indicated that proceeds from the sale of recovered copper and zinc would be sufficient to pay the operating costs of the bacterial sulfate reduction treatment plant.

It was established that acid mine drainage could be neutralized with certain coal combustion products without the use of lime or other conventional reagents, and that a more rapidly settling, higher density sludge was produced. This work crosscuts the concerns of the mining industry, the activities of watershed remediation, and the efforts of coal product utilization.

Airborne thermal infrared surveys were conducted over the 167 square mile Sewickley Creek Watershed, Youghiogheny River from McKeesport to Connellsville, PA, the Monongahela River from McKeesport to the West Virginia State line and 5 mile segments of the West Fork River, Buffalo Creek and Dunkard Creek in northern West Virginia. Karl Schroeder (NETL) and Jim Sams (USGS) jointly presented the results from the recent synoptic survey and remote sensing activities on the Youghiogheny River during the USGS NAWQUA Review. Karl Schroeder (NETL) presented the results from the recent synoptic survey of the Youghiogheny River during the Appalachian River II Conference.

Twelve years ago, research by current NETL employees showed that the evolved gas analysis (EGA) of coal mine overburden samples had potential for predicting the environment consequences of mining. Although the EGA technique had distinct advantages over other overburden analysis methods, the new technique suffered from instrument limitations that were difficult to overcome. Since that time, technology advancement has eliminated these problems. In 1999, EGA was reevaluated for overburden analysis by ViRoLac Industries under contract to NETL. Results of this evaluation showed that EGA

still offers unique performance advantages over conventional methods of overburden analysis, albeit at slightly higher cost.

RESULTS:

(A) Passive Treatment of Mine Drainage

Ten passive treatment systems in Pennsylvania and Maryland have been intensively monitored for up to ten years. Influent and effluent water quality data from ten anoxic limestone drains (ALDs) and six reducing and alkalinity-producing systems (RAPS) have been analyzed to determine long-term performance for each of these specific unit operations. The generation of alkalinity in ALDs has not exhibited significant seasonal variations. These ALDs intercept flows ranging from about 10 to about 100 L/min. When possible, drains were designed to provide a detention time of at least 15 hours. Data obtained at four sites where sampling wells had been installed at regular intervals along the length of the ALD indicate that the rates at which the alkalinity level increases appear to be nearly first order with a half-life of about 5 hours. Thus, a minimum contact time of 15 hours ensures that at least 90% of the maximum achievable alkalinity is realized in the drain. All of the ALDs successfully add alkalinity, increasing the effluent levels by 50 to 270 ppm. The lowest increases were due to the low detention times afforded by these ALDs. ALDs that received mine water containing less than 1 mg/L of both ferric iron and aluminum have continued to produce consistent concentrations of alkalinity since their construction. However, an ALD that received 20 mg/L of aluminum experienced a rapid reduction in permeability and failed within five months.

While alkalinity is produced solely by limestone dissolution in ALDs, in RAPS it is produced by both limestone dissolution and sulfate reduction. The generation of alkalinity in the oldest-known RAPS (constructed in 1991) initially displayed seasonal variations, with significantly more sulfate reduction occurring in the warmer months. A gradual decline in the generation of alkalinity has been observed in this system, which can be attributed to a decrease in sulfate reduction rates. Most of the alkalinity production in these systems comes from limestone dissolution as opposed to sulfate reduction, which can contribute as little as 5% of the total alkalinity. Alkalinity generation rates of 15.6 - 62.4 $gd^{-1}m^{-2}$ were measured in the monitored field systems.

Dr. Terry Morrow, head of the Biology Department at Clarion University, is interested in collaborating with NETL's passive treatment project during his upcoming sabbatical leave. Dr. Morrow will help with our continued long-term monitoring as well as investigating some of the biological processes occurring within some of these systems.

Much of the data that is being collected is shared with local watershed groups; local, state and federal government agencies; high schools, colleges and universities; and others involved with project at these sites. We lend technical assistance to many of these groups in site characterization, conceptual designs of passive treatment systems, and evaluation of the performance of implemented systems. Cooperators have included: Maryland Department of the Environment (Potomac River), PA Department of Environmental Protection - Abandoned Mine Land Division (Kettle Creek), USDA-NRCS, Somerset County, PA (Stoney Creek River Improvement Project), Mill Creek Coalition & Clarion Area Watershed Improvement Committee (Mill and Little Mill Creeks), Canaan Valley Institute (Shamokin Creek), Slippery Rock Watershed Association (Slippery Rock Creek), Peters Creek Watershed Association, and

the Headwaters Charitable Trust and the Natural Resources Conservation Service (Toby Creek).

George Watzlaf was invited by Clarion University and the U. S. Forest Service to evaluate the existing acid conditions in the Buzzard Swamp Recreation Area in the Allegheny National Forest in Forest County, PA and to recommend corrective action. A letter report discussing the results of water sampling was prepared and sent to interested parties.

George Watzlaf has been participating in the Powell River Feasibility Study with the U. S. Army Corps of Engineers. All expenses including salary with overhead were provided by the Corps. The team consisted of members from Michael Baker and Associates, David Miller and Associates, Virginia Department of Mines and Minerals, Virginia Polytechnic University, U.S. Corps of Engineers, and U. S. DOE. During the week, the team evaluated and analyzed existing AMD and stream water characteristics; evaluated site constraints; evaluated abatement technologies based on chemical and physical (site) constraints and construction, operation, and maintenance costs; formulated a preliminary preferred plan with a conceptual layout; estimated measurable improvements to the ecology of the Powell River, and documented the decision/plan formulation process.

(B) Demonstration of Passive Mine Drainage Treatment and Sludge Disposal for a Large Abandoned Underground Mine Pool Discharge

George Watzlaf and Karl Schroeder visited the Brinkerton site several times to survey the site and to take physical and chemical measurements of flows into and out of the site. This site-specific information will be used to tailor the remediation project to this regionally important site. In addition, in order to determine the suitability of the on-site material for construction of ponds and dikes in the proposed wetland, much of the area has been sampled using a hand auger cores (4 ft. depth), power auger borings (6 ft depth) and pits dug with a backhoe (10 ft. depth). The material was charted by a USDA soil scientist. Much of the material was found to be unsuitable for construction. Mixing flyash with the on site material is currently being investigated.

(C) Development of Water-Powered Treatment Devices and Systems for the Swatara Creek Watershed

CONSTRUCTION Construction at the Lorberry site has taken place in 3 phases. Three 2000-gallon tanks was installed along with a delivery-system capable of diverting over 100 GPM of stream water to the treatment tanks. Two diversion wells, each of which can treat about 100 GPM of stream flow, was installed up-stream of the treatment tanks. Two settling tanks was installed down-flow of the treatment tanks. Water-powered devices will be added to the experimental system to test the possibility of metering in small amounts of chemical additives using only the power provided by the stream itself.

SOLIDS REMOVAL Fine particle size and/or low density are limiting the amount of iron settling and removal that can occur before Lorberry Creek empties into Swatara Creek. To investigate this problem, a number of samples of field-filtered solids were obtained. The solids were examined by SEM to determine the morphology of the iron and to determine if this morphology changed as a function of downstream position. Micrographs of the solid material obtained at the Rowe Tunnel discharge showed that the material lacked definition and appeared amorphous. By comparison, the material obtained further downstream occurred as a mixture of crystalline and framboidal solids. No such regularity of structure could be seen in the solids obtained at Rowe Tunnel, even at higher

magnification. None of the particles observed in the Lorberry micrographs are less than 100 nm. The smallest of the individual spheres comprising the framboids measure 150 to 400 nm and the more typical ones measure about 500 nm. The smallest of the framboids and crystalline agglomerates measured over 10 microns. This is consistent with the finding that 0.1 micrometer filters have been found to give statistically equivalent amounts of filterable solids compared to the typical 0.45 micrometer filters (USGS results). Thus, the filterable solids give little indication of a significant amount of sub-micron material.

WATER QUALITY (USGS DATA) Water quality data from Lorberry Creek samples were made available by the USGS. This data was of particular interest because it covered periods of time both before and after the installation of a Limestone Diversion Well (LDW) on Lorberry Creek. Because of the possible influence of the drought this summer, the results are not unequivocal but they are suggestive of an improvement in water quality following the installation. Part of the success is probably due to the ability of the LDW to moderate changes in pH. The down-stream pH, which had closely followed the wide fluctuations seen at source (Rowe Tunnel), has remained above a pH of 6 since the installation of the LDW. The extent of the neutralization appears to be strongest when the pH at Rowe Tunnel drops lowest. This type of behavior would be expected from the kinetics of limestone dissolution, which is faster at lower pH. Since the LDW is treating only a small portion of the total Lorberry flow, this improvement is encouraging. The fact that this effect can be seen is most likely due to the low buffering capacity of the stream.

The amount of suspended iron was calculated as the difference between the iron measured in the filtered (dissolved) and unfiltered (total) samples. The amount of suspended iron has remained fairly constant at both the source and furthest down-stream sampling sites. The suspended iron at an intermediate site appears to have increased by 2 or 3 ppm since the installation of the LDW. This may be due to the increase in iron solids generated by the more efficient upstream oxidation of ferrous (soluble) iron to ferric (insoluble) iron. Inefficiencies in the iron agglomeration and precipitation steps would promote continued iron suspension until the gentler, downstream portions of the Lorberry were reached.

(D) Bacterial Sulfate Reduction Water Treatment

A report entitled "The Application of Bacterial Sulfate Reduction Treatment to Severely Contaminated Mine Waters: Results of Three Years of Pilot Plant Testing" was prepared by Richard W. Hammack and Henk Dijkman and presented at the Copper 99-Cobre 99 Conference in Phoenix, AZ, October 10-13, 1999 and published in the Proceedings.

(E) Colloidal Sludge Characterization and Utilization

Caustic solutions, lime slurries and coal ashes were used to treat authentic acid mine drainage (AMD) and synthetic solutions formulated to simulate the composition of regional mine water. Comparisons were made of the neutralization capabilities, settling rates, and remediation solids content when using these treatments for contaminant metals removal. All of the coal ashes increased the settling rates and produced higher solids density in the sludge than conventional treatments. However, ashes from fluidized bed combustion showed promise of superior performance in neutralizing AMD. Project activities demonstrated that modest amounts of ash and AMD sludge could be incorporated into concretes for low strength applications.

(F) Geophysical and Water Quality Investigations of the Lower Youghiogheny River Basin and Sewickley Creek Watershed and other sites.

The synoptic survey found that approximately 60% of pollution loading from coal mines originated from tributaries to the Lower Youghiogheny River Basin and approximately 40 % of the loading originated from artesian discharges within the river valley. Furthermore, of the 60 % tributary loading, 44 % originates from Sewickley Creek. In addition, 26 % of the 40 % pollution loading that originates from artesian discharges within the river basin is unaccounted for, suggesting artesian discharges through the river channel.

Remote sensing surveys (thermal infrared) was flown during the night and winter months when vegetation was down and the contrast between surface- and ground-water temperatures was maximized. The thermal resolution of the employed thermal infrared sensors, 0.1 degrees centigrade, was capable of successfully identifying locations where groundwater meets the surface. The spatial resolution for these surveys was 1-meter and the altitude of the helicopter platform was 1,300 feet. Thermal plumes have been identified spilling out onto land, into and within streams and wetlands and the river. Thermal infrared data; however, can not provide water quality or volume information.

Electromagnetic (EM) and magnetic surveys were conducted at the Omega Mine before and after the injection of fly ash grout into the mine void. The grout injection was intended to exclude water from portions of the mine, and to divert contaminated mine water away from a public water supply. The purpose of the geophysical surveys was to remotely determine the final disposition of the grout and to monitor the response of the mine pool to the grout injection. Fly ash grout contains a minor amount of magnetite that was entrained in the coal during the cleaning process. Moreover, a magnetite tracer was added to grout that was injected into selected areas. The intention was to observe the final disposition of the magnetite-augmented grout using a surface magnetic survey. In the initial analysis, no differences were observed between the magnetic map acquired pre-grouting and the magnetic map acquired post-grouting. Apparently, the magnetite content of the grout was too low or the grout was placed too deep to be detected by magnetometry. Electromagnetic techniques also indicated no significant differences between pre- and post-grout surveys, probably because the mine pool was below the detection depth.

Electromagnetic surveys were conducted along a segment of the upper Potomac River to identify areas where surface water from the stream may be infiltrating into underlying mine workings. Two frequency-domain electromagnetic conductivity techniques (VLF and EM-31) were applied to the leaky stream segment. The VLF and the vertical coplanar mode of the EM-31 were optimally oriented for the detection of vertical, water-filled fractures, the expected conduits for stream water entering the mine. Although the horizontal coplanar mode of the EM-31 is better suited for detecting horizontal conductors such as water tables, this data was also recorded. Results of the surveys identified several potential water-loss zones, which were later corroborated by stream gauging measurements by the State of Maryland.

Geophysical surveys were conducted at two mine sites in Montana in support of EPA-funded mine remediation research being conducted by MSE. The Miller Mine is an abandoned underground gold mine that is the source of water with high metals content. The remediation strategy was to determine areas where groundwater was entering the mine and inject those areas with grout. This action was expected to limit the amount of water entering the mine and thereby reduce the contaminant load being discharged. Geophysics was employed to delineate areas of water-filled fractures, the potential conduits for water entering the mine. VLF surveys were conducted both within the mine and on the ground surface above the mine. Because VLF anomalies can arise from mineralized zones as well as water-filled fractures, a gradient magnetic survey was also conducted that responds to mineralization but not to water. Therefore, a comparison of VLF and magnetometry results can eliminate non-water anomalies. A target area that was identified by geophysics was subsequently drilled and grouted by MSE. Flow and water chemistry data are currently being collected to determine the effectiveness of grouting.

VLF surveys were also conducted over waste rock dumps at the Peerless Mine, an abandoned silver and base metal mine. The purpose of these surveys was to identify water-filled fracture zones that may underlie the dumps, paths of water flow through the dumps, and perched water tables within the dumps. The results of these surveys were contradictory and cannot be explained without additional work.

Presentations/Publications

Note: The following presentations and publications were all based on the FY 99 work, though many were not actually presented and or published during that time period.

Acid Base Accounting Data Determined for Mine Overburden by Programmed Temperature Oxidation by Robert LaCount, Richard W. Hammack, and Douglas Kern presented at PittCon 2000, New Orleans, LA, March 12-18, 2000.

Improving the Acid-Base Account using Programmed Temperature Oxidation and Evolved Gas Analysis by Douglas Kern, Robert LaCount, and Richard Hammack, presented at the Annual Meeting of the Acid Mine Drainage Task Force, Morgantown, WV, April 4-5, 2000.

The Application of Bacterial Sulfate Reduction Treatment to Severely Contaminated Mine Waters: Results of Three Years of Pilot Plant Testing by Richard W. Hammack and Henk Dijkman, Copper 99-Cobre 99, Phoenix, AZ, October 10-13, 1999.

The Application of Bacterial Sulfate Reduction Treatment to Acid Plant Scrubber Blowdown Water from Copper and Lead Smelters by Richard W. Hammack and Henk Dijkman, Workshop on Heavy Metal Contaminants in Water, Alta, UT, August 2-4, 1999.

Results of the Geophysical Investigations of the Miller Mine and Peerless Mine was presented to EPA and MSE, Cincinnati, OH, March 28, 2000.

George Watzlaf gave a presentation concerning the past, present, and future involvement of the DOE with the passive treatment systems at the Jennings Environmental Education Center near Slippery Rock, PA.

George was asked to give this presentation as part of a dedication of the innovative and educational passive treatment systems at Jennings and celebrate the cooperative partnership of the Jennings Water Quality Improvement Coalition in finding solutions to treat acid mine drainage. John Oliver, Secretary of the PA Dept. Of Conservation and Natural Resources delivered the Keynote Address and Robert Dolence, Deputy Secretary, PA Dept. of Environmental Protection was also a guest speaker.

Presented an invited talk (an overview and history of passive treatment technology) at the Fourth Annual Slippery Rock Watershed Coalition Symposium held at the Jennings Environmental Education Center near Slippery Rock, PA on April 16, 1999. A poster outlining NETLs involvement in passive treatment of mine drainage was also presented.

Invited to visit the Savannah River Ecology Laboratory (SREL) and University of Georgia (UGA) to discuss passive treatment of acidic, metal-laden waters. Presented a talk at both SREL and UGA on the passive treatment of acid mine drainage and NETL's research in this area.

George Watzlaf gave a presentation, "Performance of Passive Treatment Systems: Lessons Learned from a Dozen Projects" and co-taught a workshop, "Acid Mine Drainage Treatment Basics: Getting Started Right the First Time" at the National Conference on Reclamation in Roanoke, VA (combining the Fifth Annual AMD Conference and the National Coalition for Abandoned Mine Reclamation). Major sponsors were OSMRE, EPA, COE, and USDA

Acknowledgments

Project A. Mill Creek Watershed Coalition, Slippery Rock Watershed Coalition, Scott Township Conservancy, Pennsylvania Department of Environmental Protection, Maryland Department of the Environment, and U. S. Department of Agriculture - Natural Resources Conservation Service. NETL Contact - watzlaf@netl.doe.gov

Project B. Sewickley Creek Watershed Association, Western Pennsylvania Coalition of Abandoned Mine Reclamation, USDA and Westmoreland County Conservation District. NETL Contact - watzlaf@netl.doe.gov

Project C. Pennsylvania Department of Environmental Protection, Pottsville District Office, USGS, Leymone Office, and Schuylkill County Conservation District. NETL Contact - tackman@netl.doe.gov

Project D. Pacques Inc. NETL Contact - hammack@netl.doe.gov

Project E. NETL Contact - hesbach@netl.doe.gov

Project F. Pat Trimble, Mayor of Dawson, PA DEP, Greensburg Office, Youghiogheny Trails Corporation, USGS, USDA, Americorps, WPCAMLR. NETL Contact - tackman@netl.doe.gov